STATUS AND UPGRADE PLANS FOR A 20 MUON DETECTORS NETWORK AT LSBB.

Ignacio Lázaro Roche on behalf of T2DM2 collaboration

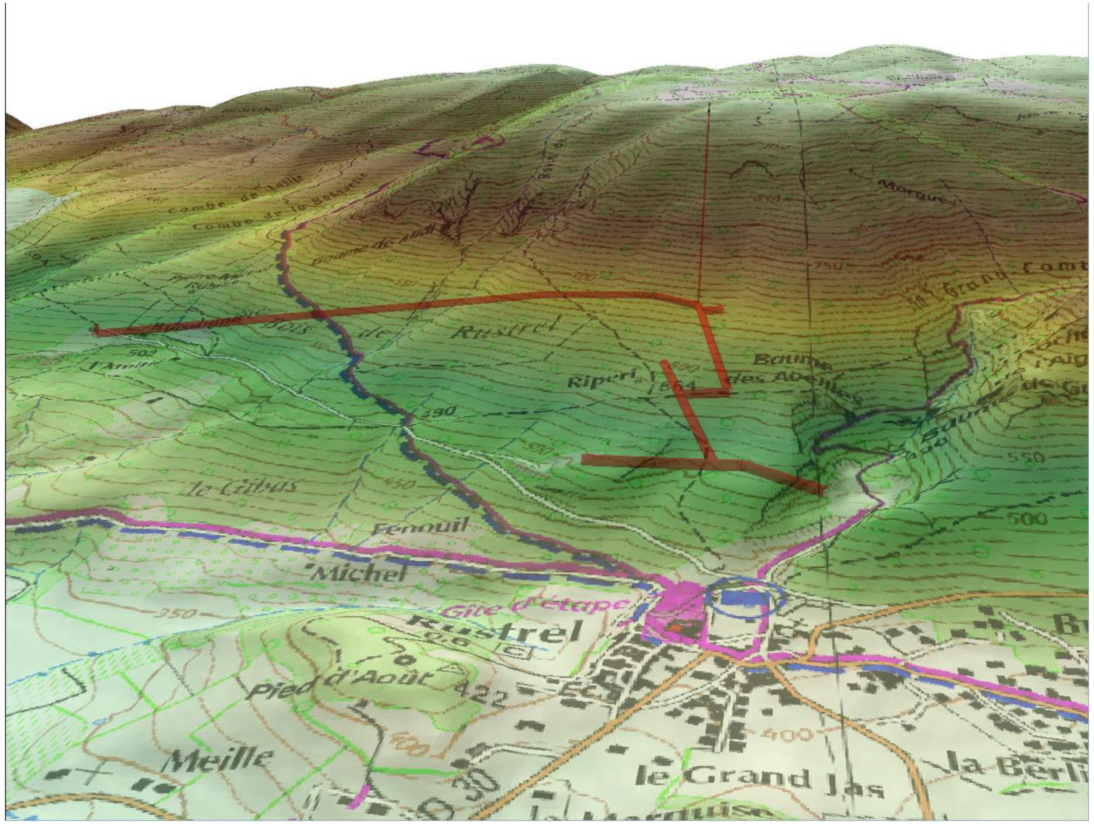
Géosciences pour une Terre durable

OBJECTIVES

- **Development of a new non-destructive, compact tool based on the measurement of cosmic muons for imaging and monitoring large volumes of matter**

  - ❑ Monitor the temporal density variations
  - ❑ New geophysics' tool based on a thin Time Projection Chamber read by a resistive Micromegas plane

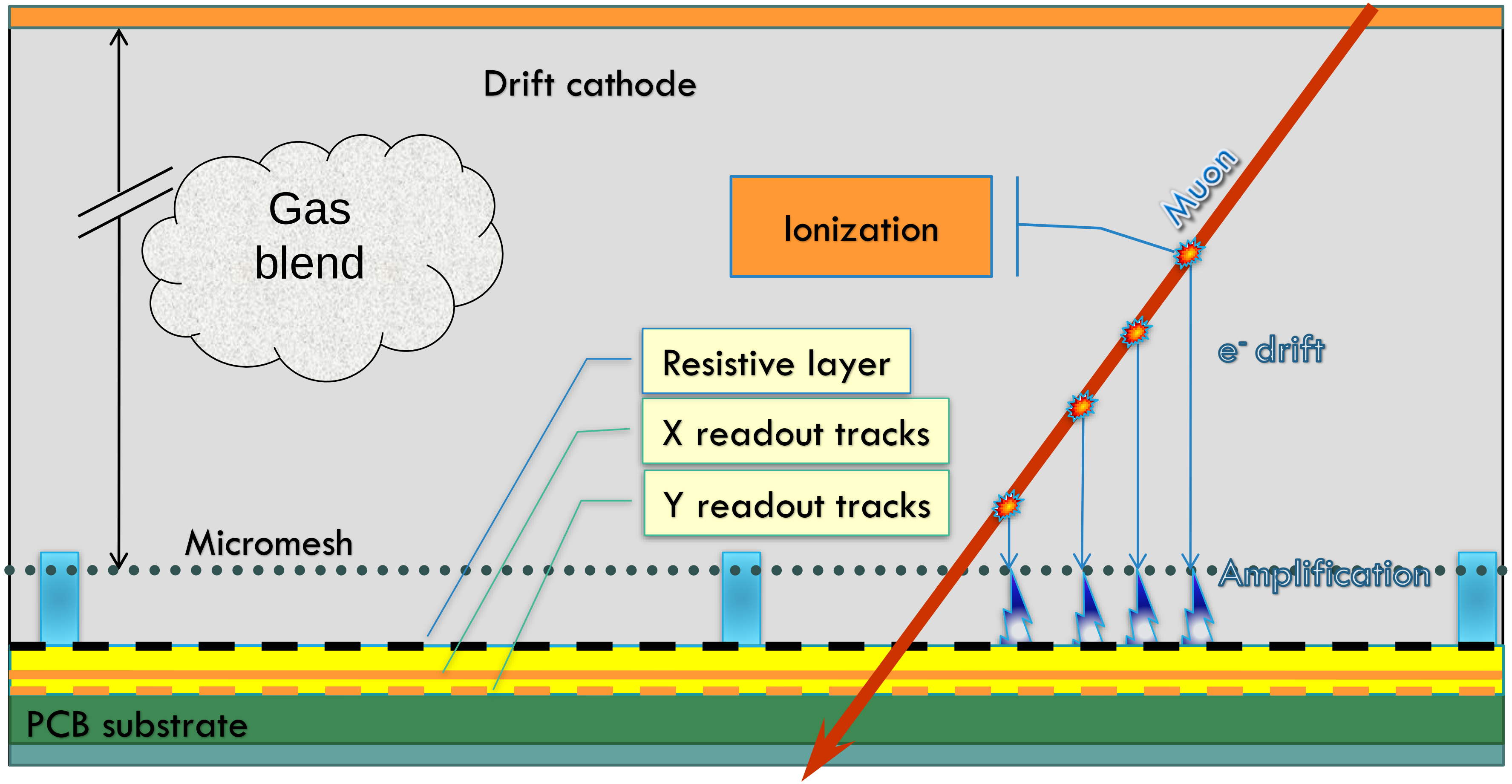
INTRODUCTION - LSBB



- Low background noise environment
- Clean room to assemble detectors
- The layout of the galleries allows to deploy the camera network easily both on the surface and underground
- Easy access and access to network, electricity, etc.
- Measurements synergy: gravimetry, MRS, hydrogeology, hydromechanical tilt, GPR…

INTRODUCTION – DETECTOR MUST²

MUon **S**urvey **T**omography based on
Micromegas detectors for **U**nreachable **S**ites **T**echnology

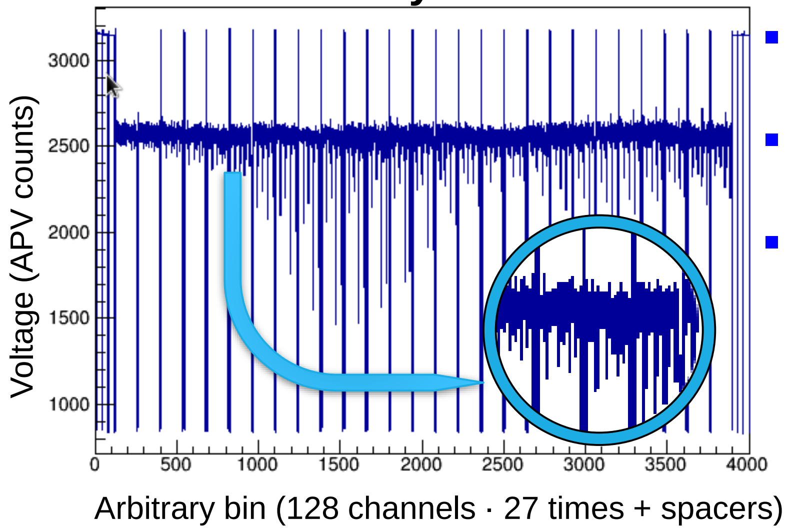


- Bulk-Micromegas
- DLC resistive layer
- 1024x512 channels
- 1mm pitch
- TPC 5cm height
- $Ar:CF_4:C_2H_{10}$ (88:10:2)
- SRS electronics
- APV25>FEC combo>PC

INTRODUCTION - DATA ACQUISITION

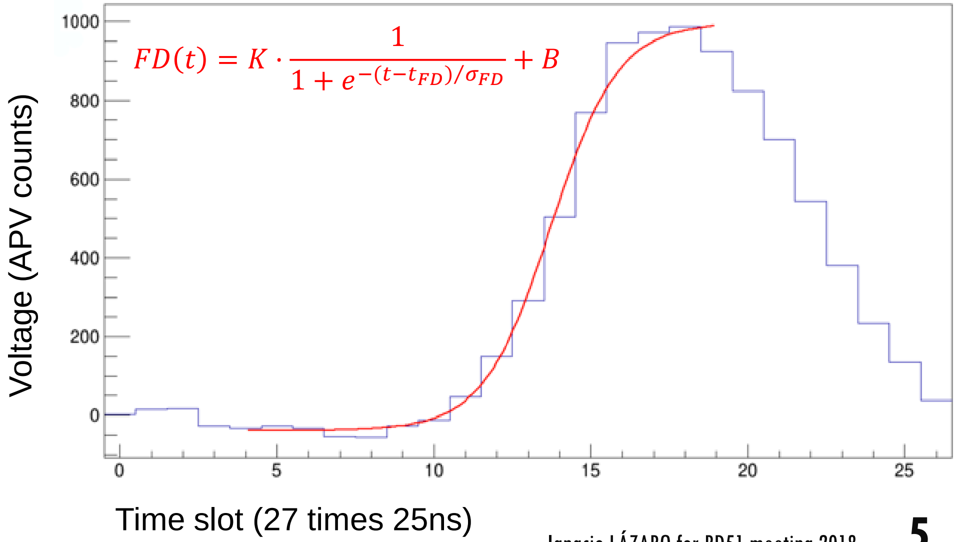
Raw data → Points → Trajectories

Example of signal acquired with an APV25 hybrid card



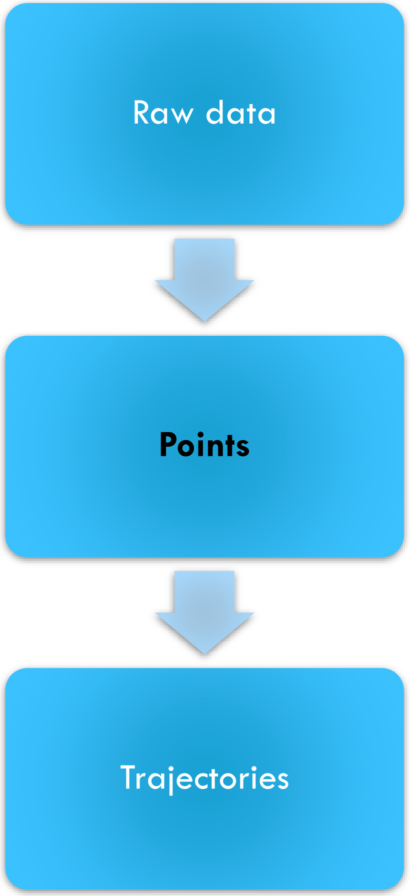
- 27 measures of V from 128 channels, 25 ns sampling rate
- The vertical bars separate the different time windows
- Every time window contains the V of 128 channels

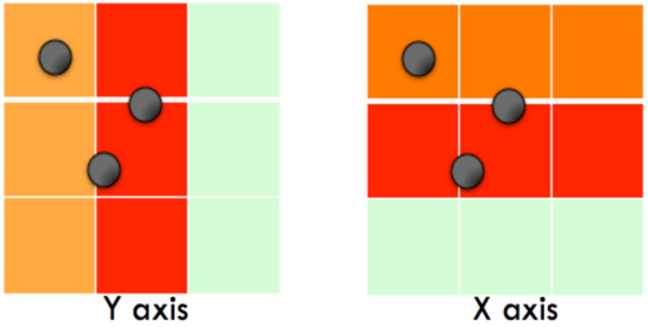
Example of signal fit with a Fermi-Dirac function for 1 isolated channel



- Reconstruction of a single channel signal shape, allows to retrieve:
  - position
  - time of passage (res. few ns)

INTRODUCTION - DATA ACQUISITION

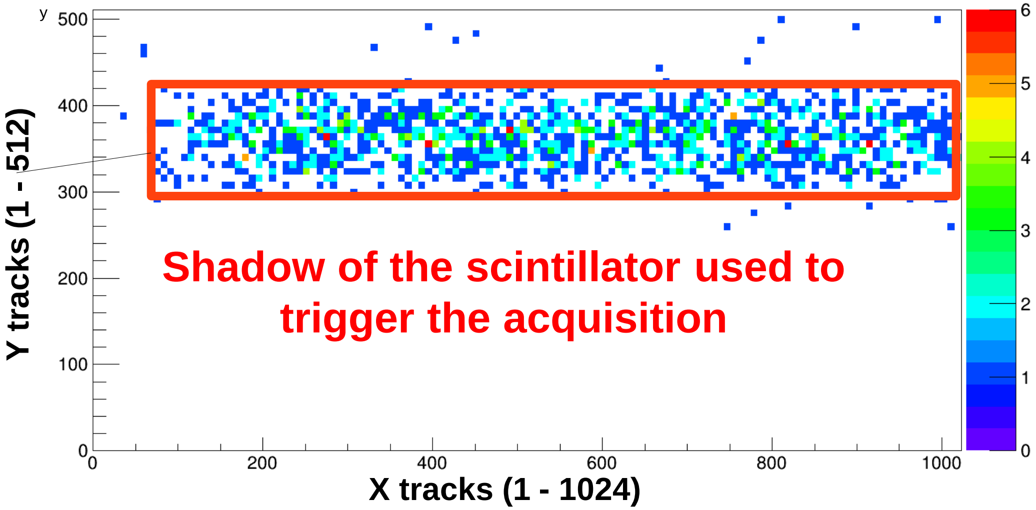




Cluster: Association of adjacent tracks hit within a fix interval

- The projection of the muon-induced electrons hits several contiguous tracks
- Reduces the number of fake events (less instrumental noise)

The combination of X & Y clusters allows reconstructing 2D points with an accuracy better than mm



Reconstruction of the retrieved points in the detector plane.

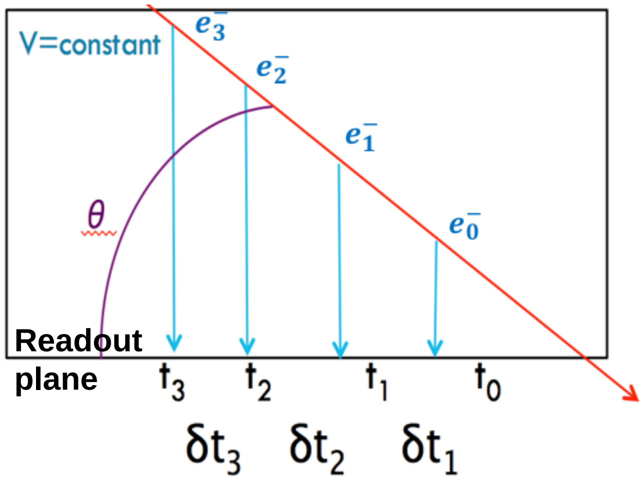
INTRODUCTION - DATA ACQUISITION

Raw data

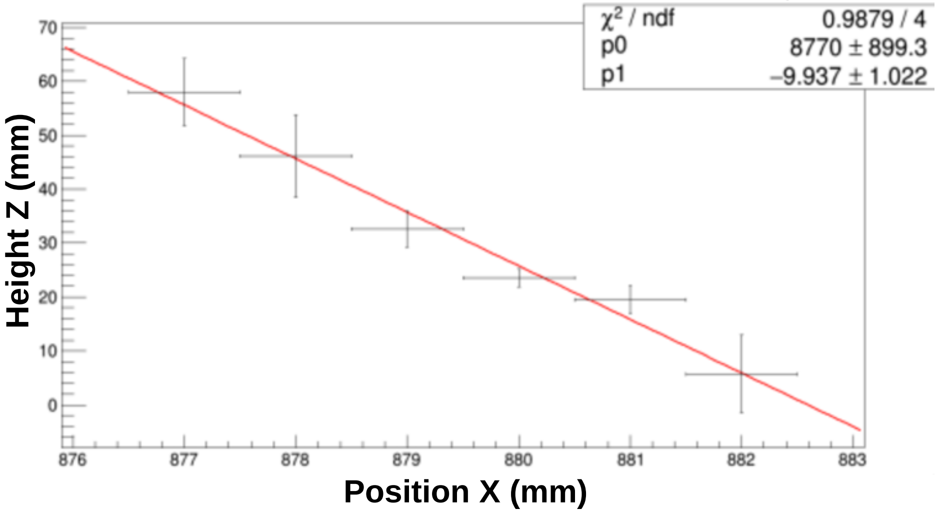
Points

Trajectories

- The arrival time of e[-] is distance-dependent
- The e[-] drift speed is known and constant for a given $\vec{E}$
- The time difference provides information about the original height of the ionization point



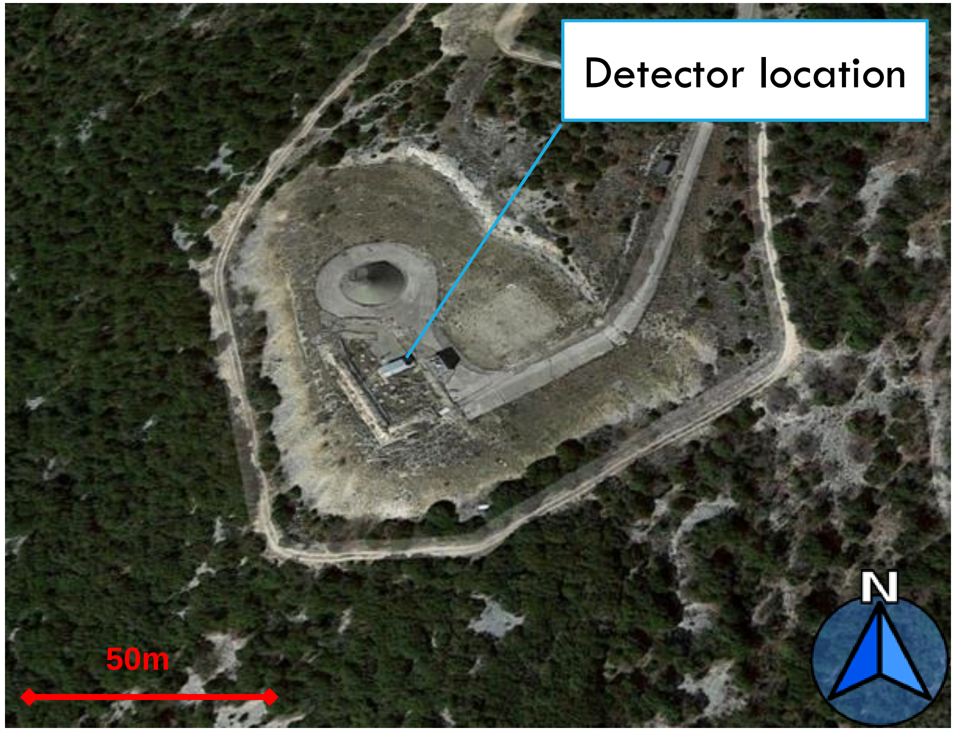
Example of lineal fit of points associated to one muon used to reconstruct its zenithal angle



- The analysis of 3D points allows to define the trajectory of the particle
- The trajectory is characterized by its Zenith (θ) and Azimuth (φ) angles

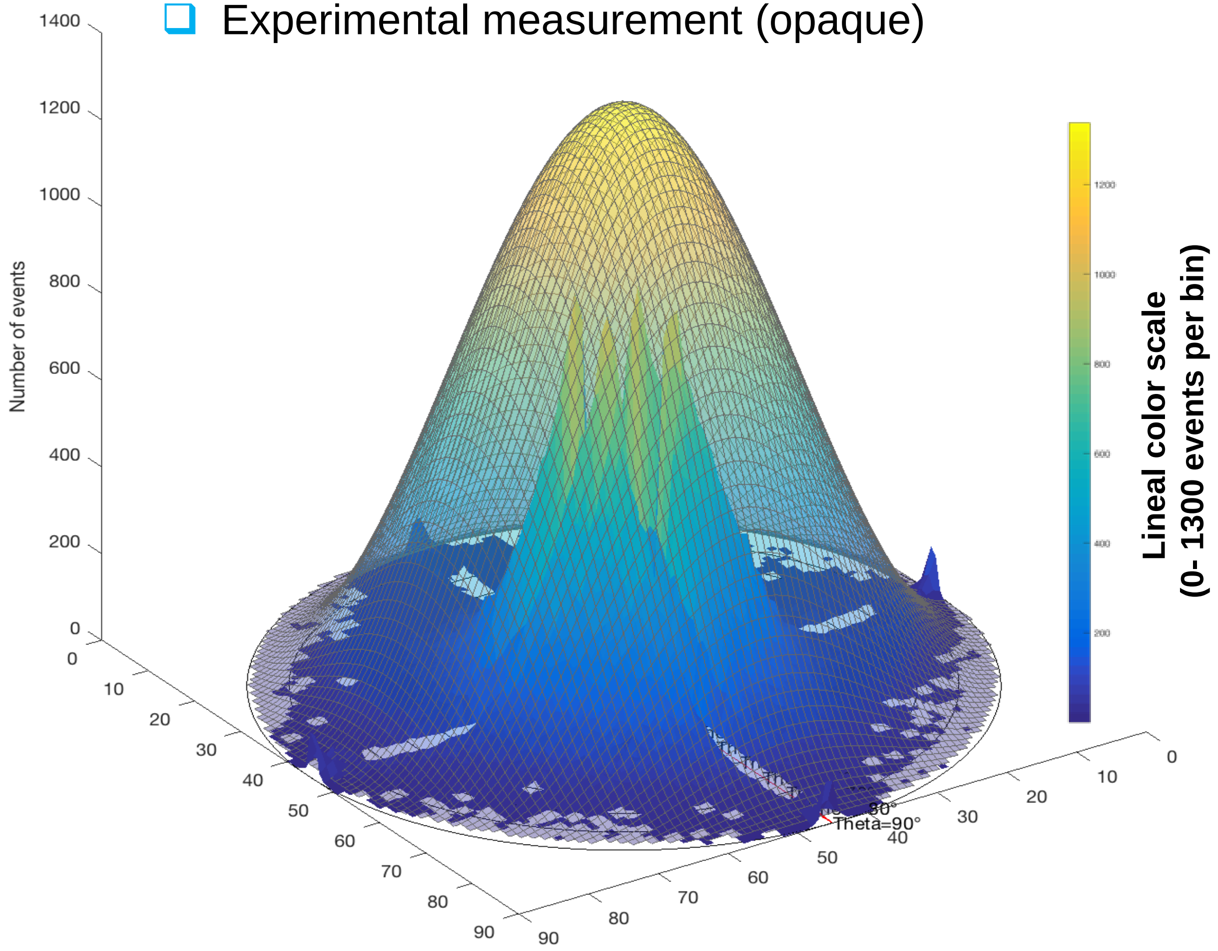
DETECTOR CALIBRATION

Aerial view of the top of the mountain hosting the LSBB, test site for open air measurements.



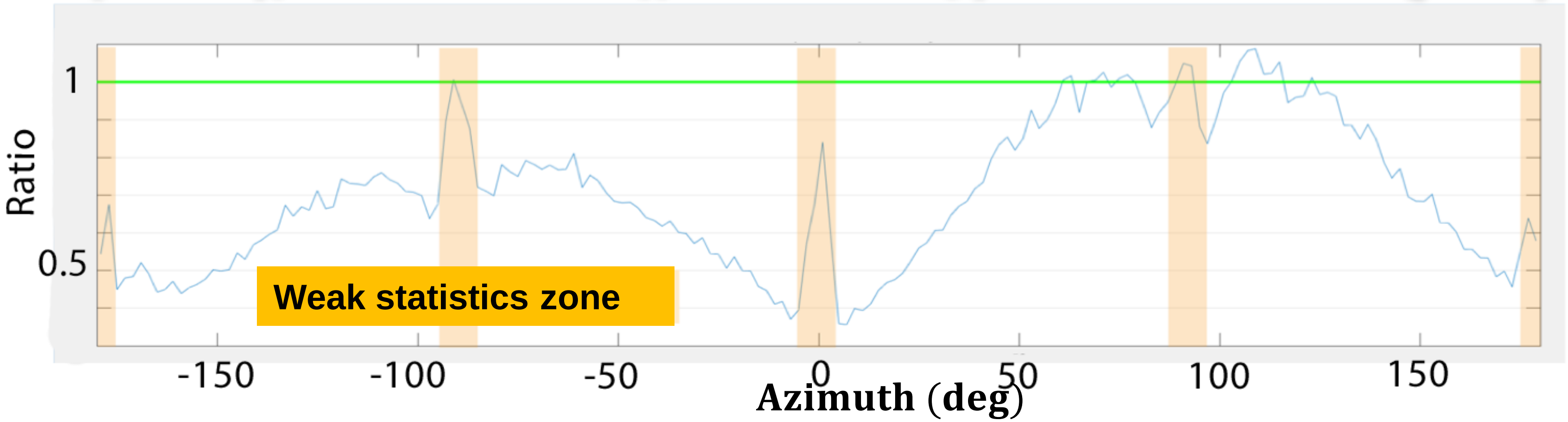
Number of muons:

- Expected according to Tang model (translucid)
- Experimental measurement (opaque)



DETECTOR CALIBRATION

$$\text{Ratio} = \frac{\text{Muons per azimuth deg } OPEN\ SKY}{\text{Muons per azimuth deg } EXP.\ MEASUREMENT}$$

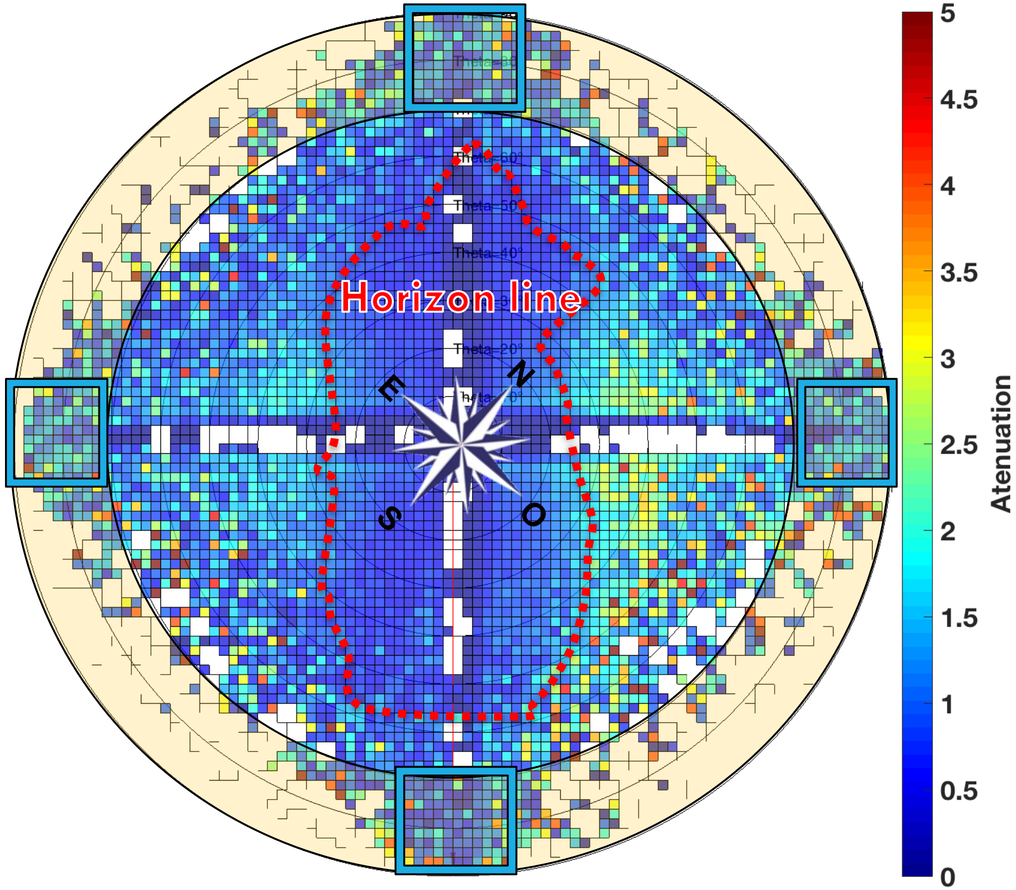


Approximation of the 360º view around the detector with the same orientation as the upper graphic

DETECTOR CALIBRATION

Approximation of the 360º view around the detector

Detector location

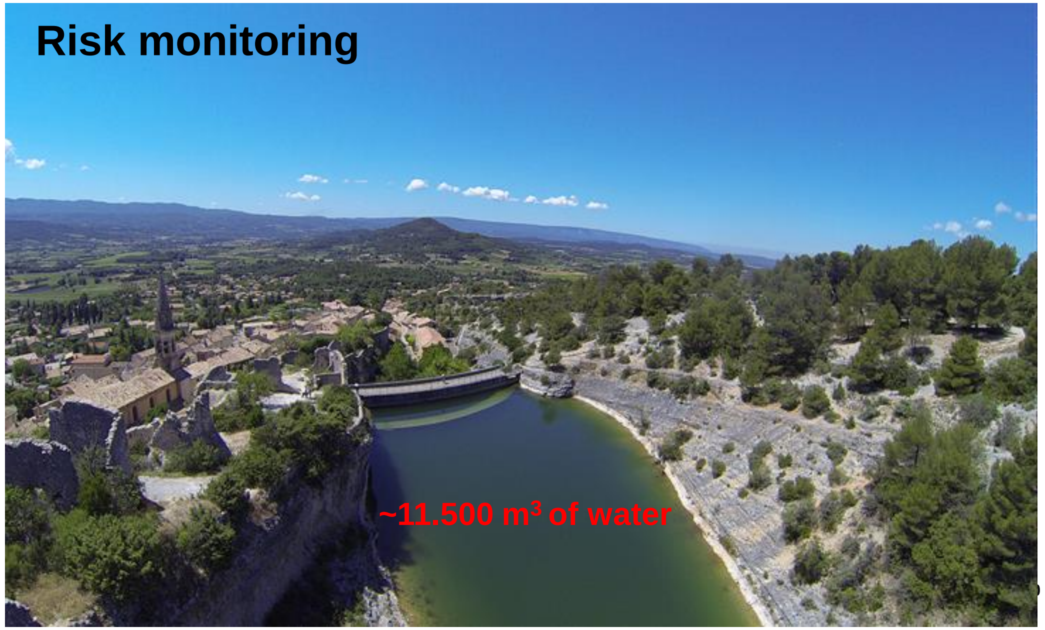


Artefacts created by the reconstruction algorithm

Weak statistics zone

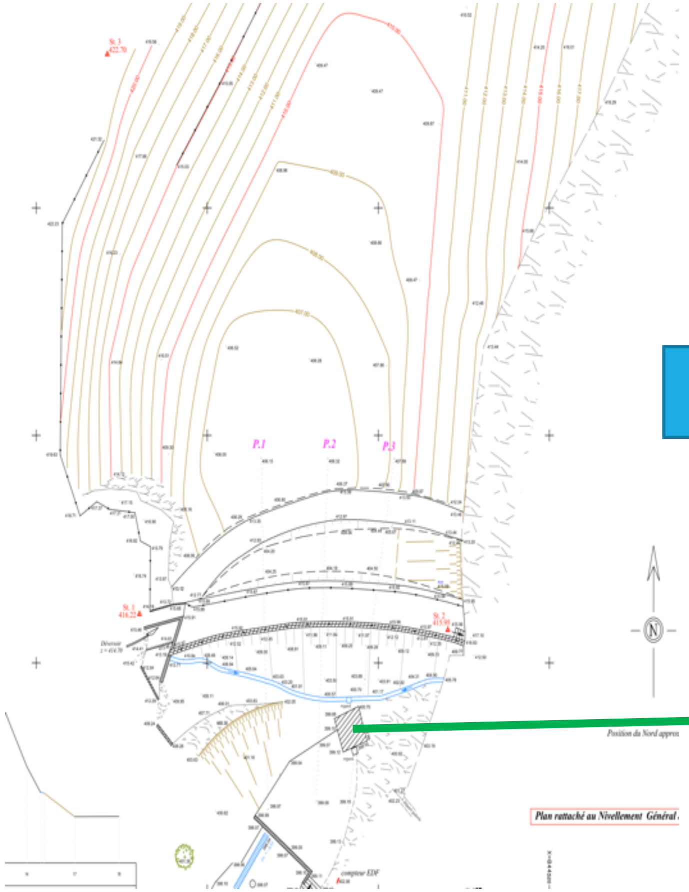
MEASUREMENTS – STUDY SITE

- **Monitored parameters:**
  - Temperature, humidity and atmospheric pressure inside the valve house
  - Level, temperature and conductivity of reservoir's water
  - Precipitations (only known water source)
  - High atmosphere pressure
  - Earth tides



MEASUREMENTS – DIGITAL MODEL

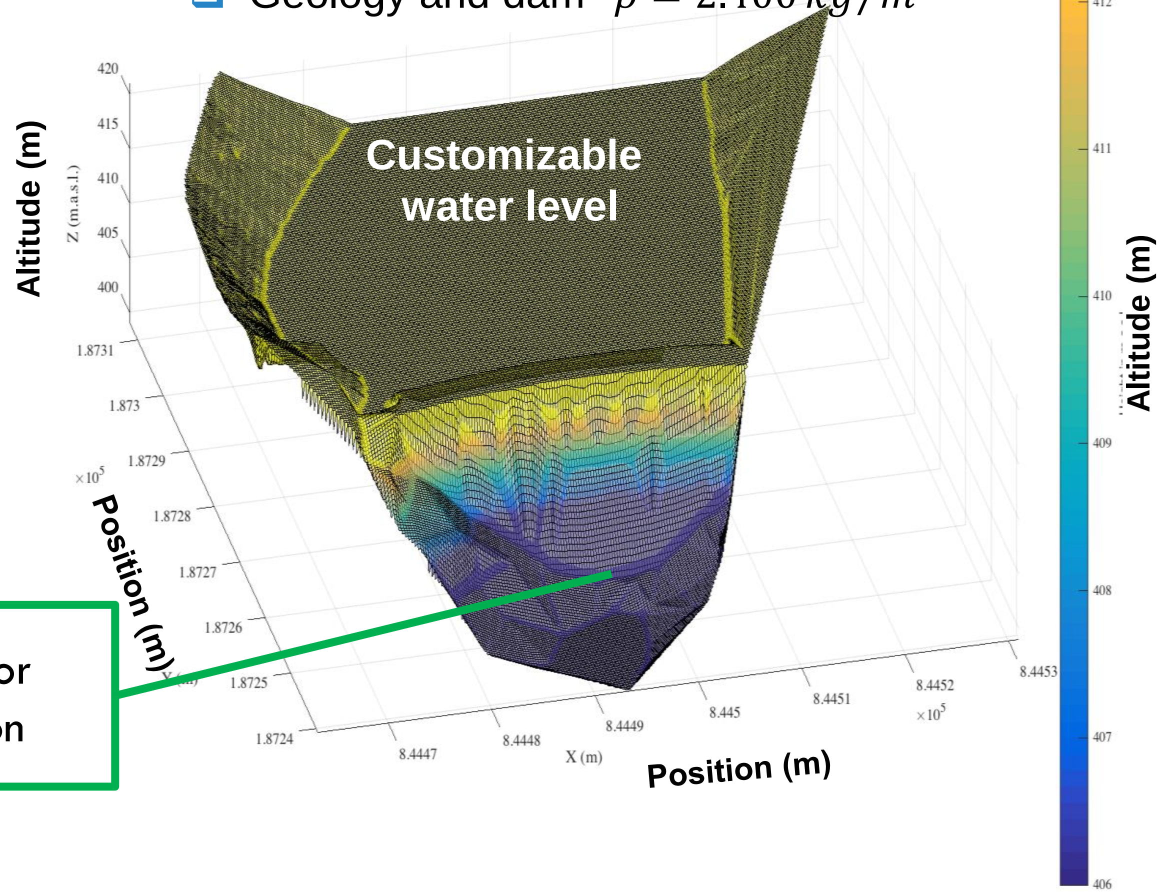
Topographic data



Source: Société du canal de Provence

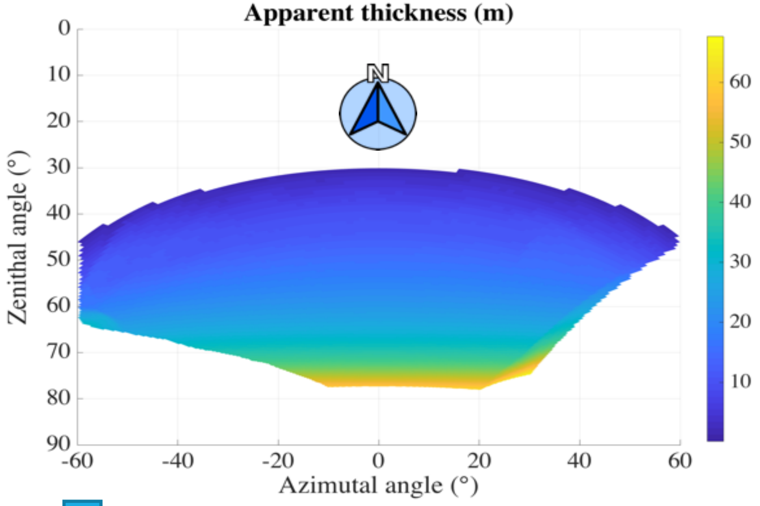
2 digital elevation models superimposed:

- Water $\rho = 1.000\, kg/m^3$
- Geology and dam* $\rho = 2.400\, kg/m^3$

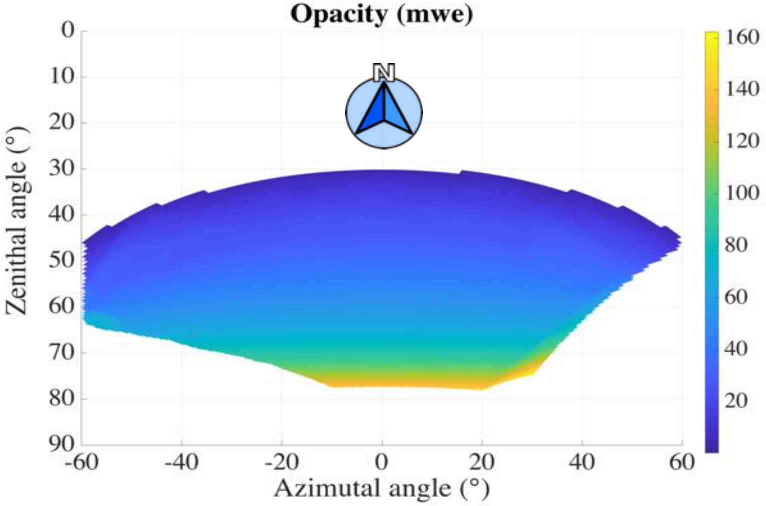


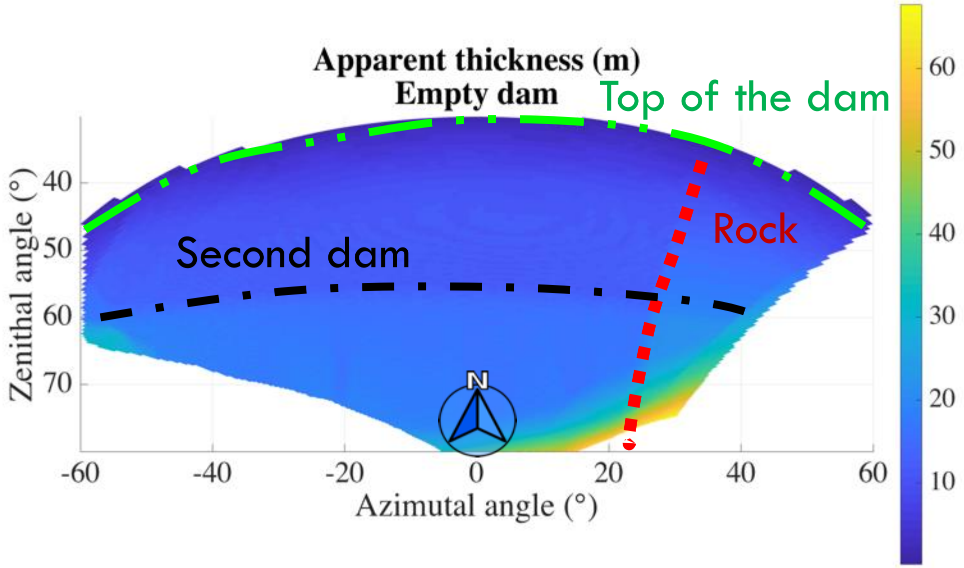
*Thanks to K. Jourde, member of T2DM2 collaboration

MEASUREMENTS – RESULTS



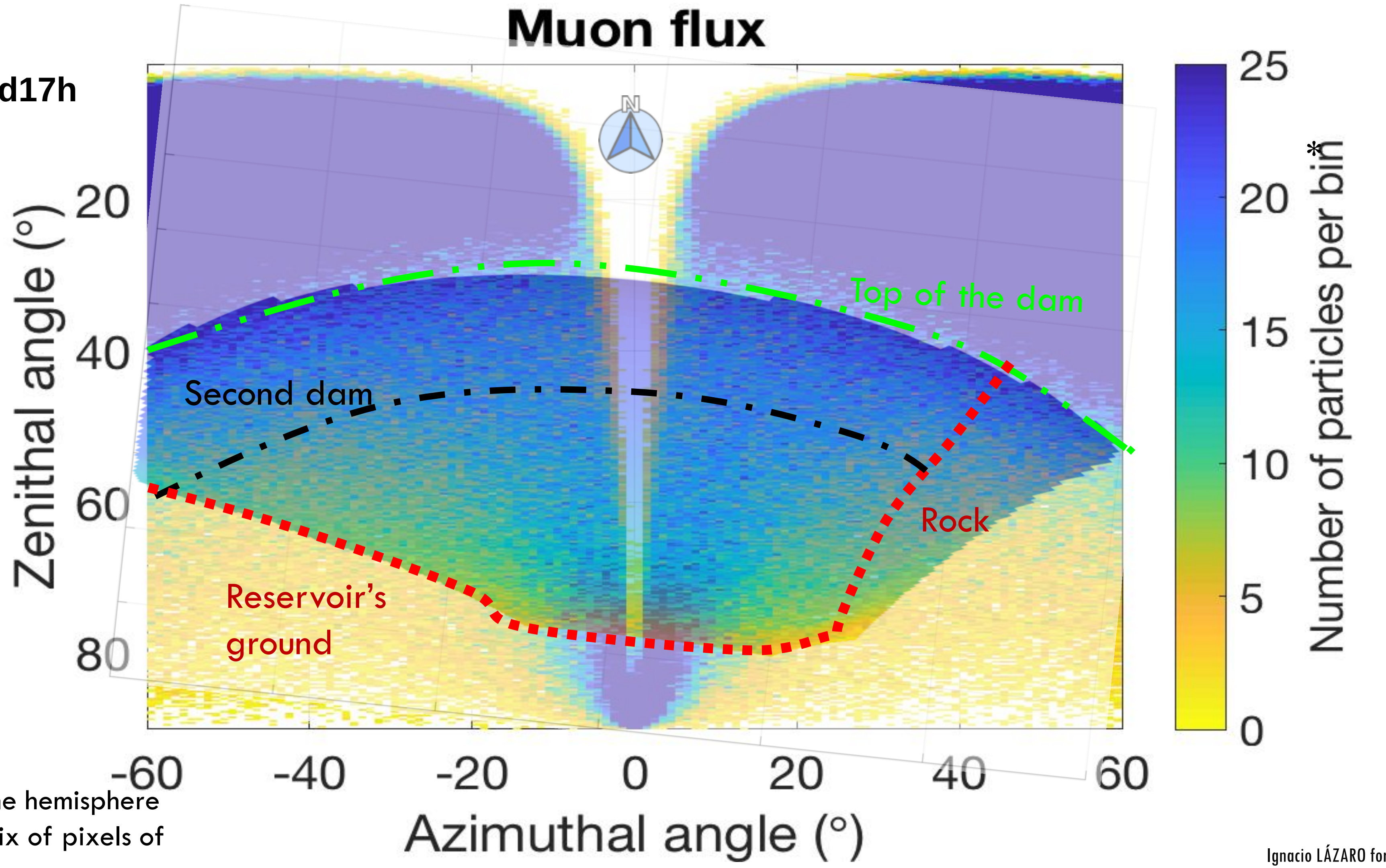
Opacity = Density · Distance





MEASUREMENTS – RESULTS

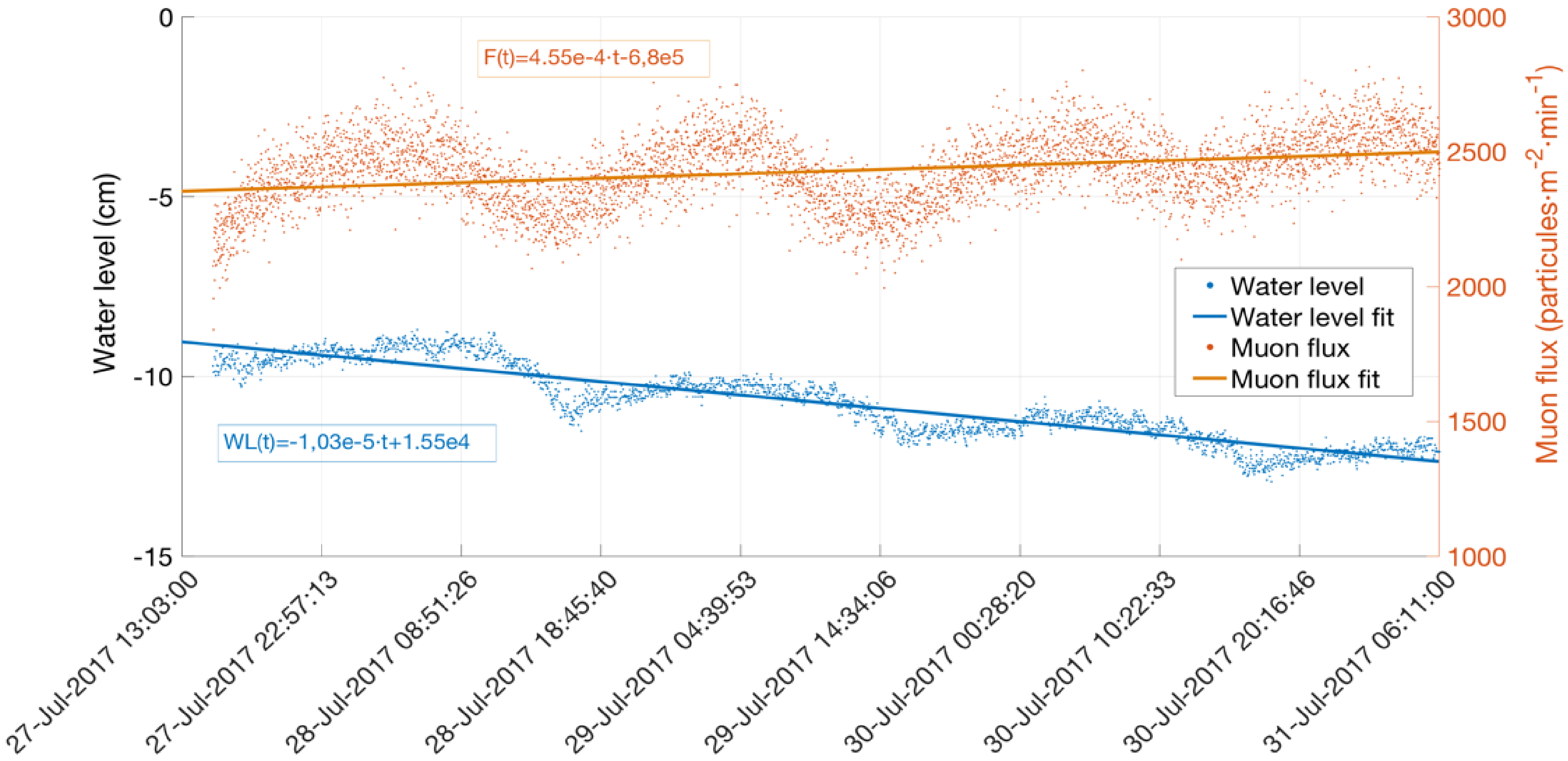
Integration time = 3d17h



*Bin = Representation of the hemisphere over the detector in a matrix of pixels of dimension 360x360

MEASUREMENTS – RESULTS

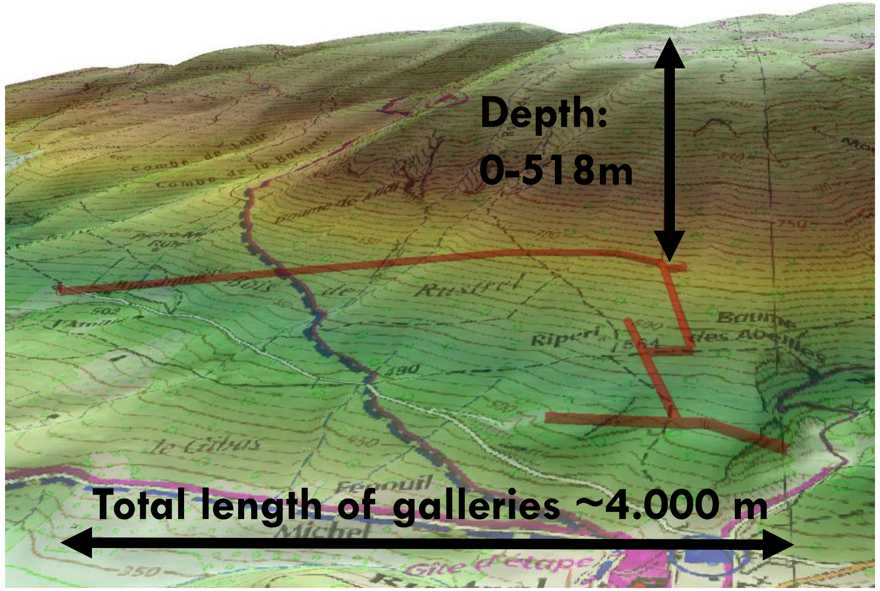
Temporal evolution of muon flux and water level



- **Strong sine-wave behaviour due to the effect of the temperature in both the barometer used to determine the water level and the MUST^2 detector**
- **The linear regression of the whole data shows that the emptying trend of the dam is related to a rise of the muon flux**

OUTLOOK

- ✓Monitor the water transfer in the non-saturated zone above the galleries
- ✓Construction and deployment of a network of 20 autonomous detectors
- ✓Roughly the same design as the previous version, but smaller and squared (50x50cm^2)
- ✓Versatile set up configurations: isolated, clustered, stacked, aligned surface/underground…



CONCLUSIONS

- ✓Very encouraging results from the first acquisition test under real field conditions
- ✓Field transportability and reliability demonstrated : possibility to do long term campaigns
- ✓The track reconstruction algorithm and noise filtering has room for improvement in order to enhance the robustness of the results
- ✓Next step: more experimental data and further data analysis development is required to support the numerical model and resolve the inversion and obtain the medium density

Acknowledgements

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cnrs dépasser les frontières
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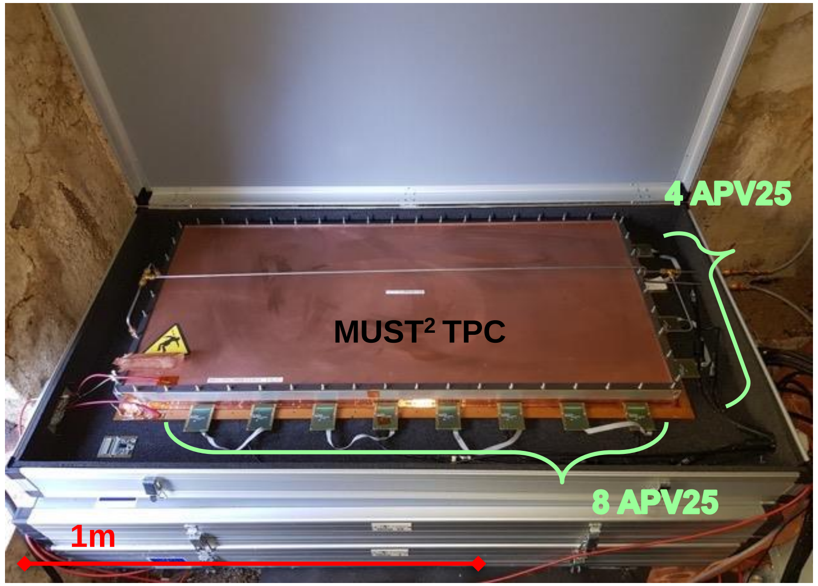
SPARE SLIDES

View of the detector inside the valve house of the dam the during the data acquisition



Scintillateurs

MUST² detector